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Geology, Development History, and Exploration Alternatives for Gypsum and Anhydrite Resources near Sussex (Part of NTS 21 H/12 and 21 H/13), Kings County, South-central New Brunswick

T.C. Webb

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Minister of Natural Resources and Energy

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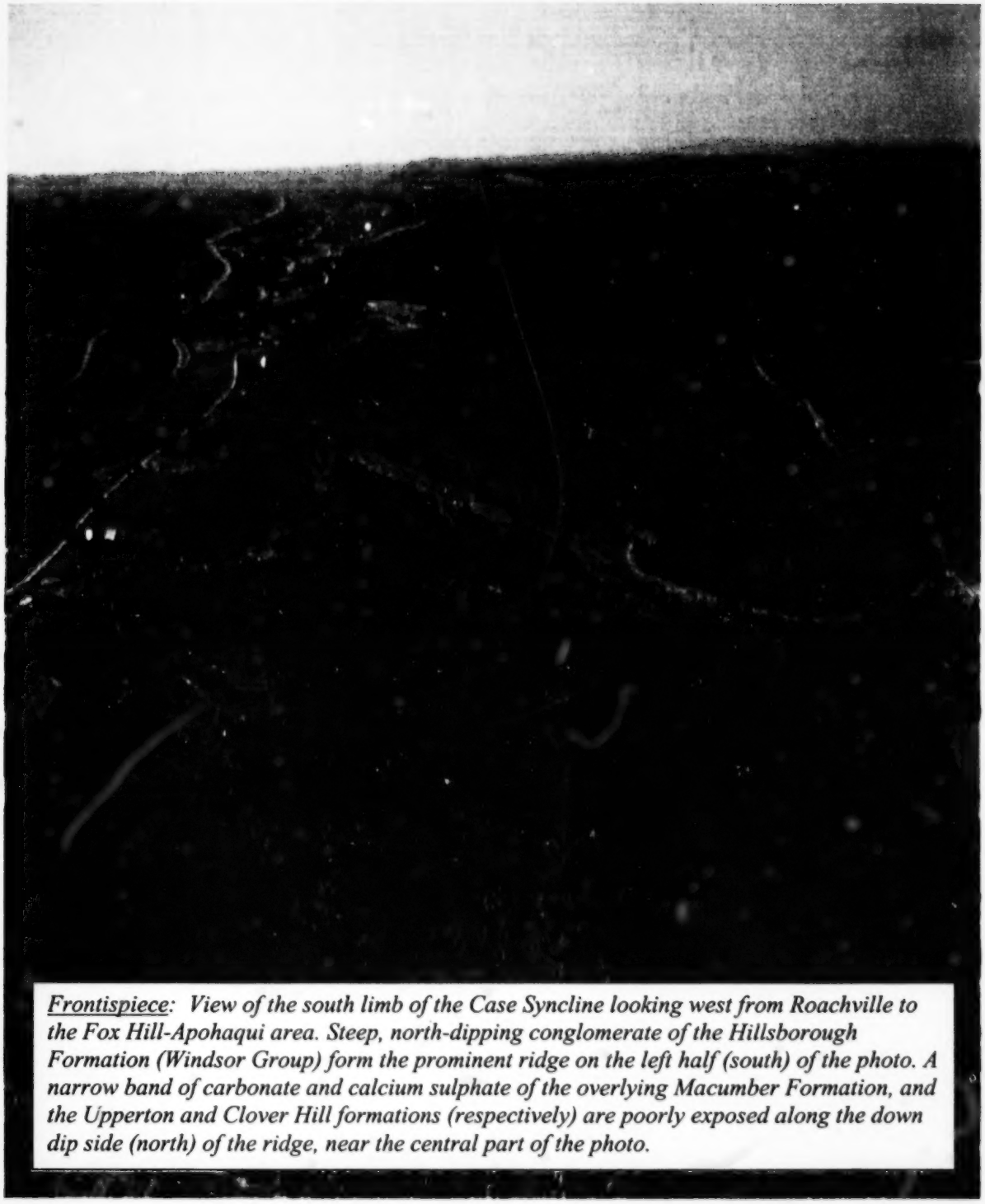


<u>Frontispiece</u>: View of the south limb of the Case Syncline looking west from Roachville to the Fox Hill-Apohaqui area. Steep, north-dipping conglomerate of the Hillsborough Formation (Windsor Group) form the prominent ridge on the left half (south) of the photo. A narrow band of carbonate and calcium sulphate of the overlying Macumber Formation, and the Upperton and Clover Hill formations (respectively) are poorly exposed along the down dip side (north) of the ridge, near the central part of the photo.

ABSTRACT

Near-surface deposits of calcium sulphate occur near the Town of Sussex, in Kings County, south-central New Brunswick. Both bedded primary anhydrite ($CaSO_4$) and secondary, bedded to massive gypsum [hydrated anhydrite ($CaSO_4 \cdot 2H_2O$)] are present.

The sulphate rocks belong to the Lower Carboniferous, Upperton and Clover Hill formations, part of a sequence of continental sedimentary rocks and marine carbonates, sulphates and related chlorides, collectively referred to as the Windsor Group. In the Sussex area, deposits of anhydrite and gypsum are generally confined to narrow, steeply dipping bands on the northern and southern limbs of the Case Syncline, a major northeast-trending structural feature in the western part of the Moncton Subbasin of the Maritimes Basin.

Gypsum resources in the region vary from typically thin (less than a few metres thick), irregular deposits resulting from shallow, surface-downward hydration to thicker more massive deposits (several metres thick), situated near fault zones and are therefore linked to the structural development of the region.

With the exception of limited use for local agricultural purposes, gypsum in the Sussex area has no recorded production history. Limited exploration, restricted largely to the southern limb of the Case Syncline, a few kilometres west of Sussex, has so far failed to locate a suitable resource for development. Despite the lack of success no less than four prospective areas remain north and west of Sussex where stratigraphy, geology, and physical setting appear favorable for small tonnage, relatively high quality gypsum deposits. At least one site north of the town has the potential for a large anhydrite resource.

RÉSUMÉ

Des gisements subaffleurants de sulfate de calcium occupent le sous-sol près de la ville de Sussex, comté de Kings, dans le centre-sud du Nouveau-Brunswick. De l'anhydrite primaire litée ($CaSO_4$) et du gypse secondaire lité à massif [anhydrite hydratée ($CaSO_4 \cdot 2H_2O$)] y sont présents.

Les roches de sulfate sont rattachées aux formations du Carbonifère inférieur d'Upperton et de Clover Hill, qui font partie d'une séquence de roches sédimentaires continentales et de carbonates, de sulfates et de chlorures connexes marins, collectivement appelés le groupe de Windsor. Dans la région de Sussex, les gisements d'anhydrite et de gypse sont généralement confinés à d'étroites bandes fortement inclinées sur les flancs septentrional et méridional du pli synclinal Case, un élément structural important orienté vers le nord-est dans la partie occidentale du sous-bassin de Moncton du bassin des Maritimes.

Les ressources en gypse de la région varient des gîtes irréguliers généralement minces (de moins de quelques mètres d'épaisseur), provenant d'une hydratation peu profonde de la surface vers le bas, aux gîtes plus massifs et plus épais (de plusieurs mètres d'épaisseur), situés près des zones faillées. Elles sont par conséquent liées au développement structural de la région.

Mis à part son utilisation limitée à des fins agricoles locales, le gypse de la région de Sussex n'a pas fait l'objet d'une production documentée par le passé. L'exploration limitée, en grande partie restreinte au flanc méridional du pli synclinal Case, à quelques kilomètres à l'ouest de Sussex, n'est jusqu'ici pas parvenue à repérer des réserves convenables en vue d'une mise en valeur. Malgré cet insuccès, il reste au moins quatre secteurs prometteurs au nord et à l'ouest de Sussex où la stratigraphie, la géologie et le cadre physique semblent favorables à la présence de gîtes de gypse de qualité relativement élevée et de tonnage réduit. Au moins un emplacement au nord de la ville présente un potentiel de réserves substantielles d'anhydrite.

Geology, development history, and exploration alternatives for gypsum and anhydrite near Sussex, (parts of NTS 21 H/12 and 21 H/13), Kings County, south-central New Brunswick

Introduction:

General location: Several interconnected narrow bands of calcium sulphate comprising a mixture of gypsum and anhydrite, occur within 3 to 4 km north and west of the Town of Sussex, in the eastern half of Kings County, south-central New Brunswick. The area of primary interest with respect to sulphate deposits occupies approximately 17 km^2, bounded by Rouse Brook to the northwest, Fox Hill to the southwest, Sussex to the south and McGregor Brook to northeast (Figure 1).

Sussex is strategically positioned between New Brunswick's three largest cities: Fredericton (120 km to the northwest), Moncton (75 km northeast) and Saint John, the Province's largest seaport (70 km southeast). Often referred to as the *"The Heart of Kings County"* Sussex is the regional service nucleus for health care and education, shopping and related business/industrial activities, and recreational facilities, serving a rural population base of 35 000. With long-established industries in agriculture (*i.e.* dairy and related farming initiatives), forestry (*i.e.* lumber milling) and mining (*i.e.* potash mining and processing), Sussex has become a leading transportation, manufacturing and distribution center in Atlantic Canada.

General physical setting and access: Calcium sulphate deposits north and west of Sussex occur in what can best be described as a ridge and valley topographic setting; a 2 km wide northeasterly trending valley (see frontispiece) bounded by a narrow ridge (*i.e.* 60 m high) to the south and a broad area of rugged hilly terrain (*i.e.* with elevations up to 240 m) to the north. Deposits of gypsum and anhydrite are typically restricted to narrow bands up to a few hundred meters wide, generally confined to low-lying wetland areas near the base of the elevated terrains in three broad geographic areas (Figure 1 and Map Plate 2001-4, Appendix E).

A sulphate band (the Mud Lake-Rouse Brook deposit) extends from the Mud Lake-McGregor Brook area, a few km north of Sussex, to the Rouse Brook area approximately 5 km to the southeast (#1 on Figure 1). Although sulphate rocks are not well exposed, their surface expression is revealed by a terrain characterized by a series of water-filled sinkholes and adjacent areas of cedar wetland. Such terrain is typical for the eastern half of the band underlying a densely forested (deciduous trees) area east of Highway No. 10 (the former Trans Canada Highway No. 2). Access to this particular area is fairly restricted.

The western extension of the sulphate band (*i.e.* west of Highway No. 10) is somewhat narrower and is located at a higher elevation than its eastern counterpart. It is one of the few areas where sulphate is exposed. In general,

the area is characterized by a light forest cover of coniferous and deciduous trees. An intermittent stream and associated wetland with several water-filled sinkholes connect with Rouse Brook.

A second band of sulphate extends for 5-6 km southwest of Roachville to the Millstream River (# 2, Figure 1 and Map Plate 2001-4, Appendix E). The physical setting of this band (the Apohaqui-Fox Hill-Roachville sulphate deposit) is characterized by a narrow, low-lying area of wetland, similar to the Mud Lake-Rouse Brook deposit to the northeast. The scattered occurrence of small water-filled sinkholes and a locally developed karst landscape is fairly typical of the terrain. The sulphate deposit parallels and is within 350 m of the old Saint John Road (Highway Route No.121). It is reached by several old logging and farm access roads that traverse a prominent steep ridge (*i.e.* "Fox Hill"). This area is a mix of light to dense forest cover with several large intervening tracts of open fields and pastureland.

A third sulphate band (the McGregor Brook sulphate deposit) is traceable for 3 km through the east-central part of the Sussex map area (# 3, Figure 1 and Map Plate 2001-4, Appendix E). It lies between the Mud Lake-Rouse Brook sulphate deposit to the north and the Apohaqui-Fox Hill-Roachville deposit to the south. Geographically the deposit is restricted to an area bounded by McGregor Brook to the north and Highway Route No. 890, the Smith Creek Road-Roachville Road to the south. Although not exposed, the presence and extent of the sulphate deposits are determined by following a line of dry and wet sinkholes. The McGregor Brook sulphate apparently extends northeast, to Smith Creek outside the present area of interest. Its southwestern limit is traceable to the Myles Road, east of the Highway Route No. 10, north of Roachville. This area is characterized by broad, gentle slopping hillsides, differing somewhat from the more rugged sulphate terrains in other parts of the region. The surface expression of McGregor Brook deposit is revealed through several dry sinkholes and related collapse structures.

McGregor Brook to the north and Smith Creek to the south provide the main drainage network to the area. For the most part, the deposit occupies the crest of a low hill not more than 30 m high. About 90% of the area is open field and pastureland, providing excellent access to most parts of the proposed sulphate deposit.

Landscape features: In general the distribution calcium sulphate resources near Sussex is displayed locally through the development of a natural karst. This landscape feature typically takes the form of an irregular to hummocky surface topography developed where underlying soft gypsiferous bedrock has been dissolved and abraded by circulating ground water generally unsaturated with respect to $CaSO_4$. This often results in the formation of a network of subsurface interconnected cavities of various sizes (Figure 2). Eventually the surface expression of these subterranean structures appear as a "sink or sinkhole", a result of structural weaknesses in overlying rock and its subsequent collapse into the cavity below forming a closed depression. Surface and related ground water may drain through these sinkholes. Should the subterranean

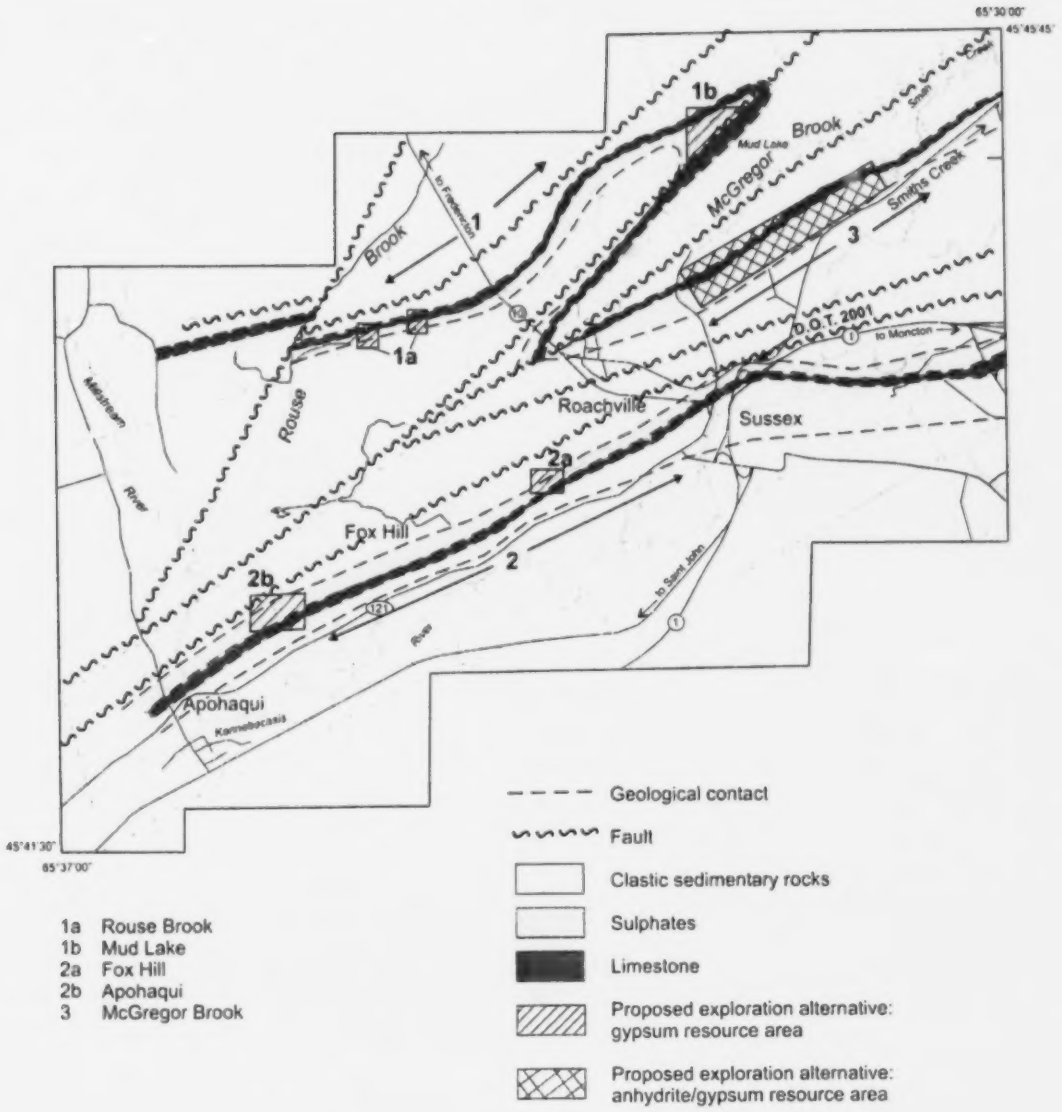


Figure 1. Location, geology and exploration alternatives for gypsum / anhydrite near the Town of Sussex, eastern half of Kings County, south-central New Brunswick.

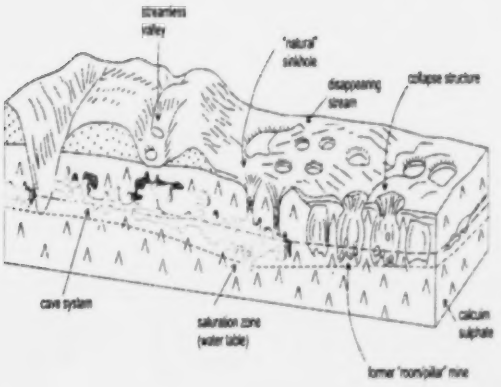


Figure 2. Underground solution and mechanical erosion of sulphate deposits produces subterranean cave networks and drainage systems, the surface expression of which is referred to as karst – a collection of unique surface topography, featuring dry and water-filled sinkholes, stream-less valleys, and streams that drain into the subsurface.

plumbing system of the structure become clogged they may fill with water forming small lakes and ponds, sometimes referred to as dolines or dolinas. Although the surface expression of this type of landscape is common throughout the region it is particularly well developed into a rather rugged terrain near Fox Hill and the area between the Highway Route No. 10 and Mud Lake, making a ground-based assessment of these areas a rather challenging exercise.

General land use: Land use in the three areas underlain by gypsum and anhydrite is a combination of residential, light industrial and agricultural. The northernmost Mud Lake-Rouse Brook resource area is forested and has supported forest- harvesting operations at various levels in the past. This activity continues sporadically although it appears to be restricted to a few, small privately owned wood lots. The large wilderness area at the northwestern end of the resource area near Mud Lake remains virtually undeveloped in this regard. The southwestern end of the resource area was cut-over many years ago and is now the site of several large Christmas tree plantations. A power line is situated adjacent the resource in this area and follows its southwest trend. Housing and related infrastructure is quite limited in the Mud Lake-Rouse Brook resource area.

The McGregor Brook sulphate resource area is mostly agricultural land used primarily for hay and silage and cattle grazing. A residential community of several homes is established near its southwestern end.

The southernmost sulphate resource area between Roachville and the Village of Apohaqui supports a diverse land use including several Christmas tree plantations, a few large farms (accompanied by hay and silage fields and pastureland) and limited wood lot activity. Residential development in the area is established on a steep south-facing slope adjacent the old Hampton - Saint John Road (Highway Route No. 890) following the general southwest strike of the sulphate deposit. A high ridge restricts the visibility of most homes with the proposed resource area even though they are within 300 m of each other.

General Geology:

The geology north and west of Sussex has been described by Alcock and MacKenzie (1946), Gussow (1953), Hamilton and Barnett (1970), Waugh and Crosby (1975), McCutcheon (1981), St. Peter (1989a and 1989b), McLeod et. al. (1990a and 1990b) and Webb (2001).

In general, the area is underlain by several hundred meters of Late Devonian to Upper Carboniferous clastic sedimentary rocks, carbonates, calcium sulphates, and chloride salts (Table 1).

Detailed Geology:

The detailed geology of the Sussex region is presented in Map Plate 2001 - 4 (Appendix E) and is summarized in Figure 1. The distribution of rock units in the map area is controlled by several prominent regional structural features including a northeast trending syncline, referred to as the Case Syncline and a network of associated faults.

The Case Syncline with a maximum width of 5 km is traceable for 30 km southwest from the Town of Sussex to the head of Belleisle Bay. It hosts a thick sequence of Lower Carboniferous sedimentary rocks and evaporites divided into three groups (from the oldest to the youngest): the Horton, the Windsor, and the Mabou groups (Table 1).

The oldest rocks of the region, the Horton Group, occur along the southern boundary of the map area, following the northeast trend of the Kennebecasis River. The Horton is a thick sequence of sedimentary clastic rocks comprised of red and grey mudstone with minor fine- to medium-grained sandstone and conglomerate of Tournasian age.

Continental sedimentary clastic rocks and marine evaporites (*i.e.* carbonates, sulphates and chlorides) of the Visean Windsor Group overlie Horton strata. Red to grey, polymictic conglomerate and pebbly sandstone along with medium- to coarse-grained sandstone and conglomerate of the Hillsborough Formation form the base of the Windsor sequence in the Sussex region. These rocks mark the southern and northern limits of the Case Syncline in the map area. To the south Hillsborough strata, dipping 50 to 60° to the north, form a narrow, northeastly-trending ridge just north of the Kennebecasis River. South dipping (30 to 50°) Hillsborough conglomerates are exposed along the north limb of the structure, extending northeastward between Rouse Brook and Mud Lake.

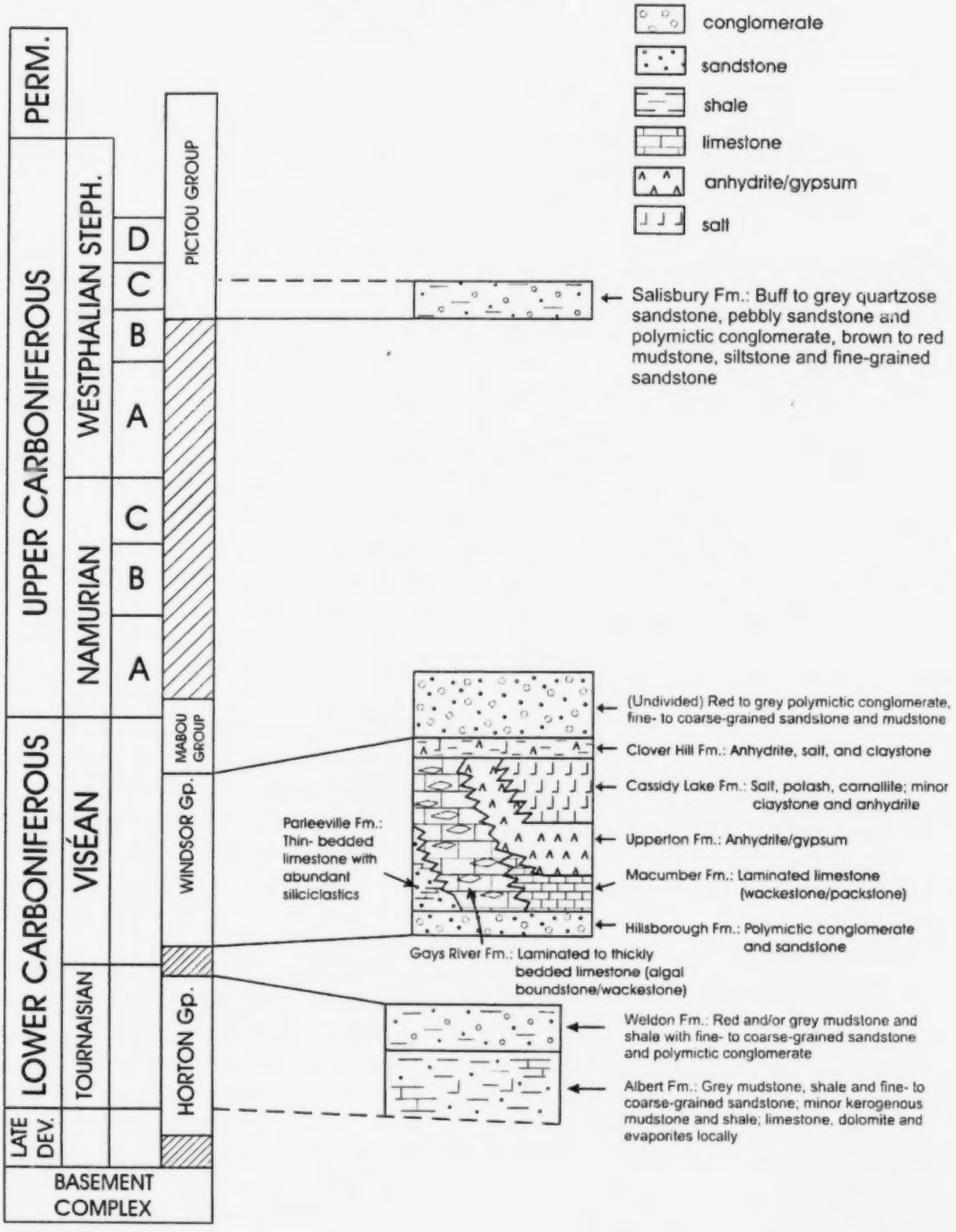
Evaporites, in the Windsor Group consist of carbonate, sulphate, various chlorides (sodium-, potassium- and magnesium-bearing) and claystone, that conformably overlie the Hillsborough clastic rocks (Figure 1). The carbonate strata that form the base of the sequence are divided into three litho-stratigraphic units: the Macumber, Gays River and Parleeville formations. These rocks are facies equivalents representing a transition from a basinal (Macumber) to platformal (Gays River) to shallow, near shore (Parleeville) carbonate depositional setting (Figure 3).

The Macumber formation consists of dark grey to grey, laminated, intraclastic, wackestone, packstone and minor limestone breccia that are restricted to a steeply-dipping band, less than 100 m wide on the north and south limbs of the Case Syncline.

In the Mud Lake area a few km north of Sussex, thicker-bedded, algal boundstone with minor interbeds of intraclastic wackestone and packstone typical of the Gays River Formation are found stratigraphically above Macumber strata.

A third Windsor carbonate facies within the Windsor Group, the Parlleeville Formation, is inferred to occur on the

Table 1. Table of formations for the eastern part of the Case Syncline, west and north of the Town of Sussex, eastern half of Kings County, south-central New Brunswick.


conglomerate
sandstone
shale
limestone
anhydrite/gypsum
salt
PERM.
UPPER CARBONIFEROUS
LOWER CARBONIFEROUS
LATE DEV.
WESTPHALIAN
NAMURIAN
VISÉAN
TOURNAISIAN
D
C
B
A
C
B
A
PICTOU GROUP
MABOU GROUP
WINDSOR Gp.
HORTON Gp.
BASEMENT COMPLEX
Salisbury Fm.: Buff to grey quartzose sandstone, pebbly sandstone and polymictic conglomerate, brown to red mudstone, siltstone and fine-grained sandstone
(Undivided) Red to grey polymictic conglomerate, fine- to coarse-grained sandstone and mudstone
Clover Hill Fm.: Anhydrite, salt, and claystone
Cassidy Lake Fm.: Salt, potash, carnallite; minor claystone and anhydrite
Upperton Fm.: Anhydrite/gypsum
Macumber Fm.: Laminated limestone (wackestone/packstone)
Hillsborough Fm.: Polymictic conglomerate and sandstone
Parleeville Fm.: Thin- bedded limestone with abundant siliciclastics
Gays River Fm.: Laminated to thickly bedded limestone (algal boundstone/wackestone)
Weldon Fm.: Red and/or grey mudstone and shale with fine- to coarse-grained sandstone and polymictic conglomerate
Albert Fm.: Grey mudstone, shale and fine- to coarse-grained sandstone; minor kerogenous mudstone and shale; limestone, dolomite and evaporites locally

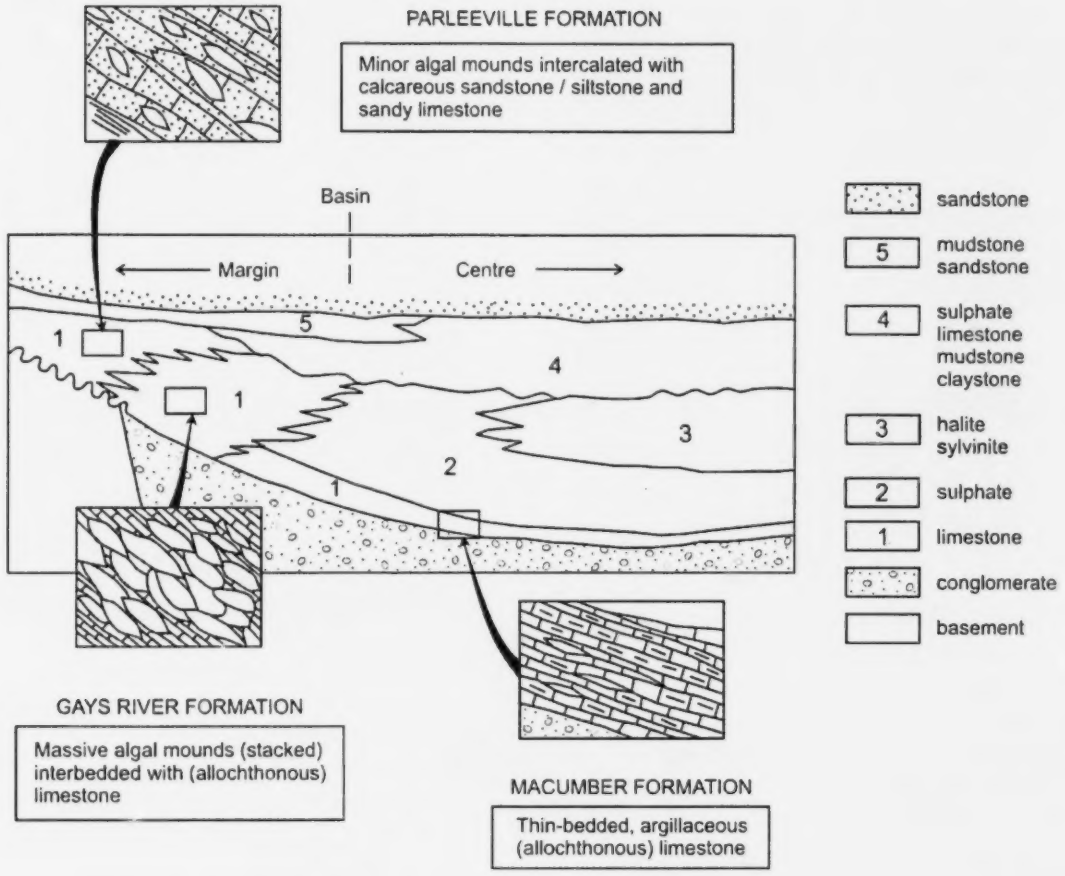


Figure 3. General facies relationships within the Windsor Group, western half of Moncton Subbasin in south-central New Brunswick (Webb 1997).

northern flank of the syncline near the western boundary of the map area. Although not exposed in the map area, these rocks are represented by thin-bedded, siliciclastic algal carbonates a few kilometers to the west.

The calcium sulphate deposits of the Upperton Formation conformably overlie and are intercalated with the upper part of the Macumber and lower part of the Gays River carbonates. The Upperton consists of mottled light grey to white, massive to bedded anhydrite locally hydrated to gypsum in most surface outcrops. The Upperton is restricted to narrow (100 to 300 m wide) northeasterly trending bands found on opposing sides of the Case Syncline. On the north side, Upperton sulphate extends 6 to 7 km east of Rouse Brook to Mud Lake and another 8 to 10 km from McGregor Brook to Smith Creek. On the south side of the syncline, Upperton sulphate strata can be traced from the Apohaqui area northeast to Roachville, a distance of about 5 km.

Evaporites belonging to the Cassidy Lake Formation overlie the Upperton strata. Although the formation is not exposed it has been intersected in the subsurface by several 800 m+ drill holes just west of Apohaqui, near the axial part of the syncline. These rocks comprise an interbedded sequence of chloride salts including halite, sylvinite, and carnallitite a few hundred meters thick. Sulphates (*i.e.* anhydrite, gypsiferous anhydrite and anhydritic gypsum,), chloride evaporites (*i.e* halite) and argillaceous clastics (*i.e.* anhydritic claystone, claystone) of the Clover Hill Formation overlie the Cassidy Lake . evaporites. Along the north and south limbs of the syncline, Clover Hill strata directly overlies Upperton sulphate, a consequence of dissolution of intervening Cassidy Lake chlorides and the subsequent collapse of overlying sulphate and claystone. In areas near northeastly trending regional fault structures (*i.e.* the Kennbecasis and Kennebecasis River faults), Clover Hill strata is juxtaposed against Upperton sulphate.

Among the youngest Carboniferous rocks in the map area is a sequence of fine-to coarse-grained sedimentary clastics referred to as the Mabou Group. Providing a thick cover to underlying Windsor evaporite strata, the Mabou reflects the general northeast structural trend of the region. On the south flank of the Case Syncline, these rocks dip 50 to 60° to the north whereas on the north flank dips are to the south in the 20 to 40° range.

Apart from the Case Syncline, several northeast trending regional fault systems (*i.e.* the Kennebecasis, the Smith Creek, the Berry Mills, the Kennebecasis River, and the Jordan Mountain faults) and a series of north-south intrabasinal faults are important to the structural development of the region. These faults play a key role in the distribution of calcium sulphate and related mineral deposits throughout the region (see below).

Calcium sulphate deposits

Calcium sulphate deposits in the Sussex area are generally restricted to narrow, sinuous bands trending northeasterly along the northern and southern flanks of the Case Syncline. Sulphate rocks are not well exposed and for the most part, the local development of a karst landscape (*i.e.* sink holes) and stratigraphic correlation with associated rock units serve as the basis for their often inferred distribution throughout the area. The general characteristics of the resource rely largely on information gathered from two areas: near Rouse Brook (#1b on Figure 1), on the northern flank of the syncline and at Fox Hill (#2b on Figure 1), on the southern flank.

About 3.5 km northwest of Sussex, gypsiferous anhydrite to anhydritic gypsum of the Upperton Formation is exposed in a 4 to5 m cliff face (Figure 4), about 800 m east of where Rouse Brook crosses under a northeast-southwest-trending power line. The exposed sulphate unit at this location, dips 70° to the south. Although its surface exposure is restricted to a zone of only 100 to 150 m wide, local landscape features suggest the unit may extend over a strike length of several hundred meters. It appears that a north-south, and northeasterly trending system of faults establish a western, eastern and northern limit to the deposit.

Figure 4. Exposure of bedded anhydritic gypsum and gypsiferous anhydrite, north limb of Case Syncline, near Rouse Brook, a few km *northwest of the Town of Sussex, eastern half of Kings County, south-central New Brunswick.*

The gypsum is greyish white to white, and occurs in beds a few centimeters thick (Figure 5). It is frequently interbedded with anhydrite and anhydritic gypsum. A multitude of sub-vertical fractures cut across bedding resulting in a rapid exfoliation of gypsiferous material.

A second area where fairly detailed information exists on the sulphate resource of the region is situated about 3 km west of Sussex, in karst terrain near Fox Hill (#2b on Figure 1). Although this area has been sporadically explored for gypsum since the mid-1950's, gypsum outcrops are very scarce. Most

Figure 5. Interbedded greyish white to white gypsiferous anhydrite and anhydritic gypsum (close-up view of Figure 4).

of what is known about the resource has been gathered from 20 drill holes scattered along a strike length of approximately 2.5 km (Map Plate 2001-4, Appendix E). The Fox Hill deposit, a combination of Clover Hill and Upperton sulphate, dips steeply to the north and has a surface width of about 200 to 300 m. Recent descriptions by Whaley (1997) reflect: *"a mottled anhydrite with fractures containing white, soft gypsum"* [and].... *"a grey gypsum with numerous fractured sections containing soft, white gypsum and gypsum interbedded with grey limestone"*. Earlier accounts by Rowbottom (1960) and others report mottled gypsum accompanied by selenite veins in a massive grey anhydrite.

A review of the past drilling results for the Fox Hill area suggests that most of

the sulphate deposit explored to date is dominated by anhydrite. There appears to be a higher incidence of 92% + gypsum, 3 to 8 m thick near the eastern limit of the explored area; however it is not known whether this gypsiferous zone is traceable further along strike to the northeast. It is suggested that the isolated nature of gypsum deposits in this area may be related to the development of narrow zones of hydration adjacent north-south and northeast trending fault structures.

Deposit Type:

Calcium sulphate is typically the product of chemical precipitation from saturated brines resulting from evaporation at the air-water interface in marine basinal and related environmental settings. It is suggested that calcium sulphate in the Sussex area were originally deposited in the form of the mineral anhydrite in a deep-water, marine basin (Figure 6). Sulphate crystals generated at the air-water interface would have gradually settled on the sea floor forming primary bedded selenitic gypsum in shallow water and thick sequences of laminar anhydrite in deeper waters.

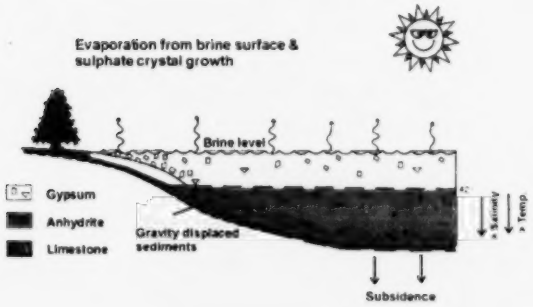


Figure 6. Typical depositional setting for primary calcium sulphate deposits.

It appears that a considerable portion of the gypsum resource of the region is the product of hydration of primary anhydrite (*i.e.* absorption of water molecules into the anhydrite mineral structure). The structural development of the region with respect to syn- and post-depositional faulting and associated fracture systems have had a direct impact on the effectiveness of the hydration process and the spatial relationship between gypsum and anhydrite (Figure 10).

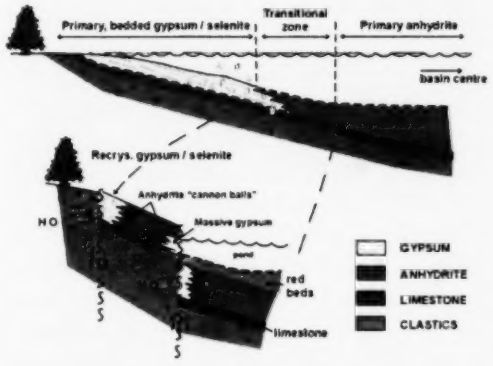


Figure 7. Formation of some gypsum deposits in the Sussex area may be directly linked to active hydration fronts developed adjacent to faults and related fracture zones.

The deposits also have been altered by various episodes of recrystallization throughout their long history as well as some limited hydration from downward percolating surface waters.

Exploration and Development History:

Apart from being displayed on several regional geological maps since the early 1940's, the gypsum and anhydrite resources found west and north of

Sussex have no reported history of development and with one exception have not been the focus of detailed exploration.

Among the earliest recorded observations regarding the gypsum resources of the region is one made by Gesner in 1840, where mention is made of limestone and gypsum occurring near Studholm Millstream, near the village of Apohaqui, west of Sussex [*perhaps a reference to the deposits at Fox Hill*?]. In 1911 part of this deposit was visited and sampled by Jennison who commented on *"prominent outcrops of gypsum ...very white and compact, having the appearance of anhydrite at some points"* (Jennison 1911). In 1930, two separate descriptions of the Fox Hill deposit (#2b on Figure 1) were provided; one by Alcock (1930) and the other by Cole (1930)[1]. Both individuals report an exposed gypsum thickness exceeding "40 feet" [4 meters] and go on to suggest *"that the area underlain by the gypsum is of considerable extent"* (Cole 1930) and "*that it* [available gypsum tonnage] *is large and ... mining costs would be low"* (Alcock 1930).

In the mid-1940's, the Fox Hill deposit received some cursory attention from a Saint John lumber company interested in establishing a wallboard manufacturing facility in the region. To assist in an evaluation of the property the provincial government considered a preliminary drilling program to test the nature of the deposit in 1947. Although it was suggested that the cost of such an initiative could be recovered through establishing an appropriate royalty on any gypsum shipped outside New Brunswick, interest in the project apparently was curtailed for unknown reasons.

Interest in the Fox Hill property was renewed in 1956 when the Barrett Company of Montreal undertook a five-hole drilling and limited sampling program near the west end of the deposit (Map Plate 2001-4, Appendix E and Appendix B). Although detailed results are not available, Hamilton and Barnett (1970) report "*that anhydrite [was] the prominent form [of sulphate] there*". Others have commented on excessive overburden thickness encountered by these holes, ranging from 9 to 27 meters.

A few years later (1960), Gypsum Lime and Alabastine Limited (GLA) investigated an area adjacent to and east of the former Barrett property (Rowbottom 1960). The company originally planned 1700 ft. of core drilling; however, the intersection of anhydrite in many of the early holes resulted in the premature abandonment of the project after the completion of only 44% (744 ft. in 10 holes over 170 hectares) of the allocated drilling program. GLA drilling indicated gypsum was limited to shallow depths with thicker intersections of 80 to 93.5% gypsum restricted to only a few local areas (Appendix B). The limited tonnage of gypsum outlined was not considered large enough to warrant the continuation of the exploration program.

Twenty years later (1987), another attempt to test the extent and quality of the Fox Hill gypsum was undertaken by K.D.A. Whaley on behalf of Eastern Gypsum Limited. Eastern was investigating the development potential of several gypsum deposits in southern

[1] A sample analysis was also provided (see Appendix A)

New Brunswick as potential alternatives to supply their wallboard manufacturing facility at McAdam, in western New Brunswick, 60 km southwest of Fredericton.

A group of ten mineral claims were staked in the area and a five-hole drill program, totalling 145.8 m, was undertaken to the east of the property formerly explored by GLA (Map Plate 2001-4, Appendix E). The distribution of gypsum (>92%) in the drilled area can best be described as spotty. Gypsum thickness of 2.5, 3.0 and 4.0 m were reported in three of the five holes. With one exception, all holes were drilled to depths of 30 m and most presented thick overburden ranging between 16.5 and 18.9 m. The easternmost hole failed to intersect bedrock and was abandoned at 24.4 m. It was suggested that further work would be required to confirm the continuity of the deposit (Whaley 1997). The mineral claims covering the area have subsequently expired and no interest has been shown in the property in recent years.

The only other gypsum exploration activity in the Sussex area has been a drill hole at Roachville to verify the northeastern extent of the Fox Hill sulphate deposit. This hole, undertaken by the New Brunswick Department of Natural Resources in 1974, penetrated 18 m of overburden before it was abandoned (Crosby and Waugh 1975).

In 2001, the New Brunswick Department of Transportation undertook a drilling program in the Roachville-Kennebecasis River area, near a major highway interchange (see D.O.T. 2001 on Figure 1 and inset, "Kennebecasis River 7.0, and Kennebecasis River bridge 6.5" and "Roachville" on Map Plate 2001- 4, Appendix E and D). Although these were closely spaced holes, drilled for construction related purposes, several intersected anhydrite, anhydritic gypsum gypsiferous anhydrite and gypsum in thicknesses up to 9 m. Overburden thickness in this area ranged between 14.7 and 29.4 m.

Exploration Model:

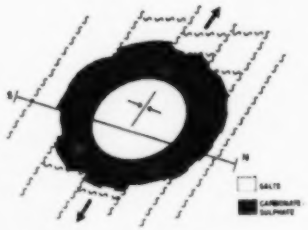
The structural and geologic evolution of the Case Syncline and adjacent area (s) may be related to development of syn-depositional steep-sided fault scarps around the periphery of a larger subsiding basin (i.e. the Moncton Subbasin of the Maritimes Basin) (Figure 8).

Deposits of carbonate and sulphate accumulating on the basin margins would have been fairly prominent physical features of this faulted terrain forming a series of ridges, steep cliffs and /or escarpments.

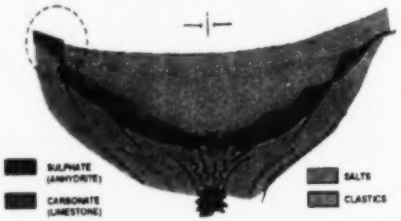
The termination of evaporite deposition in the Sussex region is marked by the gradual infilling of these basinal structure(s) by continental clastics of the Mabou Group (Figure 8). This period of sedimentation was characterized by a steady flow of sediment-laden fresh water probably from a positive source area to the south or southeast. This water flowed into the basin area, forming a series of scattered ponds or small lakes juxtaposed anhydrite fault scarps at various locations. These bodies of water would have not only have supplied continuous medium for hydration of the anhydrite to gypsum but also would have exerted considerable pressure against the

Figure 8. As Bailey so eloquently stated a long time ago, *"the [New Brunswick] gypsum deposits...are exceedingly varied in character, and in their mode of occurrence present many features of geologic interest."* (Bailey 1898). The following is offered as an alternative explanation for what appears to be a rather complex "diagenetic" origin of New Brunswick's gypsum deposits.

During the late Visean, several northeast trending oblique rift-like basins in southern New Brunswick served as important depocentres for thick evaporite deposits

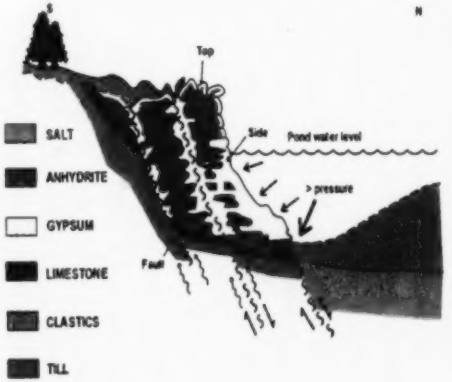


Around the periphery of these basins, syndepositional steep-sided fault scraps developed parallel and also at right angles to the axis of the basin (*i.e.* collapse structures) responding to more or less continual basinal subsidence. Deposits of carbonate and calcium sulphate accumulating on the basin margins and floor would have been fairly prominent physical features of this faulted terrain, forming a series of ridges, steep cliffs or escarpments. Considering the arid climatic conditions of the late Visean, surface hydration of any exposed anhydrite (anhydrous calcium sulphate) was probably minimal.



The termination of evaporite deposition in the basin was marked by it's gradual in-filling with continental clastics. This period of sedimentation was characterized by a steady inflow of sediment-laden fresh water. This water would have flowed into the basin probably forming a series of scattered ponds or small lakes juxtaposed the anhydrite fault scarps at various locations. These bodies of water would have not only supplied continuous contact water for anhydrite hydration but also would have exerted considerable pressure against the "anhydrite walls" contributing further to the extent of hydration within the anhydrite body.

Water penetrating the stratified anhydrite was probably selective with hydration advancing along bedding planes and major contacts as well as upward along pre-existing faults and adjacent fracture systems. The location of these ponds and periodic fluctuations in water levels within them may also have influenced the degree of local hydration..



Following this relatively early hydration event(s), various structural adjustments in the area probably resulted in the further alteration of the sulphate deposits. The effect would have been to shatter sulphate beds adjacent to faulted areas, making way for additional hydration of anhydrite and recystallization of existing gypsum (*i.e.* the formation of selenite crystals.

In the late 1950's it was suggested that New Brunswick's gypsum deposits were hydrated from anhydrite during the post Pleistocene time (Sund 1960). However, contrary to this explanation it is suggested that most of the hydration process was probably underway and mostly completed much earlier. In fact some of these deposits have (locally) undergone multiple hydration, recrystallization and possibly even some dehydration throughout their long history.

"anhydrite walls" creating fracture systems further contributing to the penetration of the hydration front within the anhydrite mass. The initial penetration of water into the anhydrite was probably selective advancing along bedding planes and major contacts (*i.e.* limestone-sulphate) as well as upward along secondary expanding fracture systems. The lower-part of this water and dissolution and subsequent column would be sediment-laden, reflected in carbonate-sulphate erosion deposition of a breccia of marlstone and red clastic strata at the interface between the Macumber limestone and the overlying Upperton and Clover Hill sulphates of the Windsor Group.

Following this relatively early hydration, later structural adjustments in the form of east-west strike-slip faulting affected the alteration and subsequent distribution of sulphate deposits in the area. The affect would have shattered sulphate beds adjacent faulted areas, making way for additional hydration of anhydrite and the subsequent recrystallization of pre-existing gypsum (*i.e.* crosscutting veins and solitary crystals of selenite). These faults may also have had a significant impact on the local thickness of the sulphate and related strata within the basin.

A secondary fault system is also recognized in the Sussex area. These structures are interpreted as north-south-trending, normal faults affecting post-Windsor and Mabou strata. They have also influenced the local hydration, recrystallization and distribution of the sulphate resource in the region.

Preliminary Deposit Evaluation:

The exploration and development potential of a large gypsum resource in the Sussex area would appear to be somewhat limited, reflected by:

1. Uncertainties and inconsistencies in the distribution and quality of gypsum versus anhydrite.

2. The narrow width and steep dipping nature of the Clover Hill and Upperton sulphate deposits.

3. High ground water levels in parts of the area (*i.e.* areas of water-filled sink holes)

4. Anticipated restrictions related to various land use issues (*i.e.* proximity to housing, to active agricultural areas) in geologically favorable areas and other restrictions affecting exploration and potential development.

Apart from these concerns, four potential resource areas are considered as unqualified exploration targets for a small-tonnage gypsum deposit (s). One area is considered a possibility for primarily anhydrite. These are listed below and appear on Figure 1 and Map Plate 2001-4 (Appendix E):

Gypsum resource area 1a (Figure 1) is situated in the northwest corner of the map area, about 3.5 km northwest of Sussex, and north of the power line that extends between Rouse Brook and Highway Route No.10 (former Trans Canada Highway Route # 2). It is characterized by a less than 100 m-wide band of sulphate and is referred to as the Rouse Brook resource area. The band

traceable over a northeast strike length of about a kilometer, dips 75° to south and appears fault-bound to the southwest, northeast and the north. White to greyish-white anhydritic gypsum and gypsiferous anhydrite is exposed in a 4 to 5 m high cliff-face (Figure 3). The deposit is typically thin bedded (*i.e* a few cm thick) and contains thin lenses, interbeds and small masses of anhydrite. The exposure features many sub-vertical joints and cracks that cut across bedding. This feature in combination with the soft nature of the gypsum results in hydration and rapid exfoliation of gypsiferous material.

The thickness and quality of the gypsum at this location is not known. However, its jointed character, its reddish to grey color, the bedded nature of the deposit seems consistent with a late hydration event, possibly from the surface downward. It is therefore expected that gypsum will grade to anhydritic gypsum and anhydrite at some point down-dip. The diffusion of the gypsum hydration-front would require additional work (*i.e.* drilling etc.) to verify.

The Rouse Brook sulphate resource area covers about five-wooded hectares adjacent a major northeast-southwest trending power line. Less than a hundred meters to the south is a reforested, cut-over and a Christmas tree plantation. Low-lying terrain featuring a small, unnamed brook and a line of water-filled sinkholes is situated less than 100 m to the north. These factors will no doubt impact any proposed exploration and subsequent development of the deposit. Apart from these physical land use concerns, the deposit is fairly remote from the nearest habitation and is accessible from the south and east via a network of private, gated logging roads.

Gypsum resource area 1b (Figure 1) is situated in the northeastern part of the map area, 3 to 4 km north of Sussex, near Mud Lake. This property is estimated to cover about 22.5 hectares. Although sulphate rocks are not exposed, the stratigraphy of the area (*i.e.* basal Macumber carbonates to the north and south) and favorable structural setting (*i.e.* faults, to the south and west) and the development of several large sinkholes (*i.e.* Mud Lake) suggest the subsurface presence of sulphate strata.

The Mud Lake resource area occupies a lightly forested, low lying terrain characterized by a relatively high water table. Mud Lake and its surrounding wetland form the most prominent water feature(s) in the area. More work would be required to confirm the presence and character of gypsum and the impact that nearby water would have on the development potential of this particular area. There are a few homes in the immediate vicinity.

Gypsum resource area 2a (Figure 1) is 1 to 2 km west of Sussex, situated between Fox Hill and Roachville and a few hundred meters north of the old Hampton Road (Highway Route No.121). This thirty-hectare site, referred to as the Roachville resource area, is an extension of Fox Hill sulphate deposit to the west. There is no data to confirm the nature or character of the Roachville sulphate resource. It does not outcrop and therefore its position is inferred, based on regional stratigraphic relationship with underlying Macumber carbonate and Hillsborough clastic rocks exposed in the area. It is however worth

noting that the Roachville area is not dominated by sinkholes, a feature commonly associated with the occurrence of sulphate in other areas. This may be due to thick overburden in a narrow valley that appears to follow the strike of the sulphate unit. Overburden thickness was found to approach 9 meters near the western (*i.e.* near Fox Hill) end of the area of interest and more than 18 meters at its eastern end, near Roachville. It may also be an indication that the underlying sulphate resource is primarily anhydrite. The recent (2001) drilling of several holes adjacent to the Kennebecasis River, south and east of the proposed site, encountered mostly anhydrite, anhydritic gypsum and gypsiferous anhydrite overlain by alluvium and till in thicknesses ranging from 14 to 36 m (see D.O.T. 2001 on Figure 1 and inset; "Kennebecasis River 7.0," and Kennebecasis River bridge 6.5" and "Roachville" on Map Plate 2001-4, Appendix E).

The Roachville property is a mix of a light forest cover (40%), open fields and pastureland (60%). Although the proposed area of sulphate is within 500 m of housing adjacent the old Hampton Highway (Highway Route No.121) and the Kenebecasis River, it is hidden from view by a high northwest-trending ridge.

Gypsum resource area 2b (Figure 1), is situated halfway between Fox Hill and Apohaqui and a few hundred meters north of the old Hampton Road (Highway Route No.121). It comprises an area of about 25 hectares, characterized by several water-filled sinkholes, indicative of a shallow ground water level over much of the proposed site. One area of higher relief near the eastern limit of the property occurs adjacent a north-south trending fault structure suggesting an unqualified possibility of an extractable deposit of massive gypsum.

A band of sulphate is suggested to occupy a low northeasterly trending ridge, just south of McGregor Brook and north of the Smith Creek Road (Highway Route No. 890), 2.5 km north of Sussex (Area #3, Figure 1). Although not exposed, the band can be traced 3 to 4 km by way of a northeasterly trending line sinkholes. These are spread out over a strike length of several hundred meters, between the Myles Road - Highway Route No.10 area on the west and the main Smith Creek-Sussex Road (Highway Route No. 890) to the east and beyond. They appear to be concentrated near proposed contacts with underlying Macumber limestone and overlying red beds of the Mabou Group.

This McGregor Brook resource area is spread out over 90 hectares, featuring a mix of open fields and pastureland (80% of area) with a limited, light forest cover (20% of area). The area decreases in elevation from 60 m near the McGregor Brook Road, eastward to 30 m, just west of the confluence of McGregor Brook and Smith Creek. Housing in the area is concentrated in the vicinity of the Myles Road and adjacent the Smith Creek and McGregor Brook roads.

With the possible exception of the area adjacent contacts with underlying carbonates and overlying sedimentary rocks it is suggested a significant portion of the underlying sulphate in this area may be anhydrite, gypsiferous anhydrite or anhydritic gypsum. Such a statement remains highly speculative in the

absence of sufficient drill hole data to determine the true nature of the sulphate resource (*i.e.* anhydrite vs. gypsum).

Conclusions:

Deposits of calcium sulphate belonging to the Upperton and Clover Hill formations of the Windsor Group occur in narrow, steeply dipping bands (*i.e.* up to 300 m in width, dipping 50 to 75°) north and west of the Town of Sussex, in the eastern half of Kings County, south-central New Brunswick.

For the most part, these deposits are in the form of anhydrite, locally hydrated to gypsum of variable quality and extent. It is suggested that hydration levels are generally shallow (less than a few meters) except in those fractured areas adjacent regional and intrabasinal fault structures (*i.e.* areas with numerous sinkholes).

In a few explored areas, local accumulations of sulphate grading between 81 and 96% gypsum have been found in thicknesses up to 4 meters. However, the extent and continuity of gypsum appears to be rather erratic. It is not known whether this characteristic is pervasive throughout the region.

Five sites throughout the map area (Map Plate 2001- 4, Appendix E and Figure 1) are considered to have unqualified potential for gypsum. Most are limited to less than 10 hectares, with gypsiferous strata restricted to areas with high ground water levels and thick overburden.

A ninety-hectare site a few kilometers north of Sussex, extending from the McGregor Brook Road northeast to Smith Creek is considered a primary exploration alternative for anhydrite.

Acknowledgements:

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APPENDIX A (p. 23)

Table of compiled chemical analysis of gypsum samples from the Fox Hill area 4 km west of the Town of Sussex, Kings County, south-central New Brunswick (1911and 1930)

APPENDIX B (p. 23)

Table of chemical analysis for gypsum / anhydrite samples from drill holes in the Fox Hill-Roachville area, near the Town of Sussex, Kings County, south-central New Brunswick

APPENDIX C (p. 28)

Summary of drilling and chemical analysis for gypsum / anhydrite intersected in the Roachville, Kennebecasis River 7.0 and Kennebecasis River Bridge 6.5 area, near the Town of Sussex, south-central New Brunswick.

Appendix D (p. 35)

Chemical analysis for selected gypsum / anhydrite core samples samples intersected by New Brunswick Dept. of Transportation drilling (2001) in the Kennebecasis River 7.0 area, near the Town of Sussex, south-central New Brunswick (see inset "Kennebecasis River 7.0" for location on Map Plate 2001-4, Appendix E.

Appendix E (p. 36)

Guide to preliminary qualitative testing of gypsum samples.

Appendix A: Table of compiled chemical analysis for gypsum samples from the Fox Hill area 4 kilometers west of the Town of Sussex, Kings County, south-central New Brunswick (1911and 1930).

	Wt %											
Source	Insol.	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	SO_4	H_2O	$CaCO_3$	Total	$CaSO_4 \cdot 2H_2O$	$CaSO_4$
Jennison, (1911)	1.20	-	-	-	32.48	tr.	46.21	20.50	-	99.69	97.86	-
Cole (1930)	1.67	0.07	-	0.11	32.26	0.25	45.34	19.45	-	99.71	92.94	0.83

Appendix B. Table of chemical analysis for gypsum / anhydrite intersected in drill holes from the Fox Hill-Roachville area, near the Town of Sussex, Kings County, south-central New Brunswick.

Drill Hole #	Overburden (meters)	Sampled interval (length in meters)	% gypsum	% anhydrite	Remarks
Five holes in 1956[1]	Note : No records available, however it is reported that gypsum was only intersected in westernmost hole with others intersecting anhydrite (Rowbottom 1960; Hamilton and Barnett 1970)				
60-1[2]	9.5	9.5-12.5 (3.0)	**93.5**	1.9	Poor core recovery (45%) noted in gypsum section with sandstone and sandstone pebbles between 12.5 and 13.5 meters
		12.8-13.1 (0.3)	26.0	**68.5**	
		13.4-14.6 (1.2)	29.7	**64.0**	
		14.6-15.8 (1.2)	**49.5**	45.1	
		15.8-50.3 (35.5)	-	-	Massive anhydrite

(1). Barrett Company Limited, 1956; (2). Gypsum Lime and Alabastine Limited , 1960; (3) New Brunswick Dept. of Natural Resources, 1975; (4) Eastern Gypsum Ltd., 1987

Appendix B (continued)

Drill Hole #	Overburden (meters)	Sampled interval (length in meters)	% gypsum	% anhydrite	Remarks
60-2	6.1	6.1-6.7 (0.6)	**84.0**	13.6	Core recovery, 60 % in gypsum section
		6.7-7.2 (0.45)	**83.2**	5.0	
		7.9-10.4 (2.4)	**89.9**	5.8	
		10.4-11.9 (1.5)	**81.4**	14.5	
		11.9-14.0 (3.1)	37.2	**58.1**	
		14.0-18.3 (4.3)	9.7	**86.2**	
		18.3-46.3 (28.0)	-	-	Massive anhydrite
60-3	7.3	7.3-8.2 (0.9)	10.7	**86.6**	Good core recovery
		8.2-8.7 (0.5)	2.6	**95.4**	
		8.7-10.7 (2.0)	2.6	**95.6**	
		10.7-20.7 (10.0)	-	-	Massive anhydrite
60-4	5.2	5.2-5.5 (0.3)	12.5	**83.0**	Good core recovery
		5.5-6.1 (0.6)	7.5	**88.8**	
		6.1-9.1 (3.0)	4.6	**91.5**	
		9.1-13.1 (4.0)	-	-	Massive anhydrite
60-5	6.7(?)	6.0-9.1(3.1)	4.5	**86.3**	From 3.3-6.7 cavity reported
		9.1-14.3 (5.2)	-	-	Massive anhydrite
60-6	8.2	8.2-9.1 (1.9)	**75.8**	21.8	Core recovery in gypsum section 80%
		9.1-10.6 (1.5)	30.7	**66.1**	
		10.6-12.1 (1.5)	21.5	**74.9**	
		13.1-13.7 (0.6)	**71.6**	25.4	
		13.7-15.5 (1.8)	13.7	**83.4**	

(1). Barrett Company Limited, 1956; (2). Gypsum Lime and Alabastine Limited , 1960; (3) New Brunswick Dept. of Natural Resources, 1975; (4) Eastern Gypsum Ltd., 1987

Appendix B (continued)

Drill Hole #	Overburden (meters)	Sampled interval (length in meters)	% gypsum	% anhydrite	Remarks
60-6 (con't)		15.5-16.8 (1.3)	5.3	**91.8**	
		16.8-20.1 (3.3)	-	-	Massive anhydrite
60-7	3.7	3.7-4.6 (0.9)	**58.8**	37.4	Core recovery 61% in gypsum section
		4.6-5.8 (1.2)	15.0	**81.2**	
		5.8-6.4 (0.6)	35.9	**58.3**	
		6.4-9.1 (2.7)	2.9	**92.5**	
		9.1-15.2 (6.1)	-	-	Massive anhydrite
60-8	3.7	3.7-5.8 (2.1)	23.1	**72.3**	
		5.8-7.3 (1.5)	4.5	**89.5**	
		7.3-9.1 (1.8)	1.3	**94.4**	
		9.1-14.0 (4.9)	-	-	Massive anhydrite
60-9	1.8	1.8-3.4 (1.6)	11.5	**80.5**	
		3.4-6.1 (2.7)	3.0	**93.2**	
		6.1-9.1 (3.0)	-	-	Massive anhydrite
60-10	4.2	4.2-5.8 (1.6)	38.6	**65.7**	
		5.8-7.3 (1.5)	17.7	**76.8**	
		7.3-9.1 (1.8)	3.7	**92.2**	
		9.1-23.8 (14.7)	-	-	Massive anhydrite

(1). Barrett Company Limited, 1956; (2). Gypsum Lime and Alabastine Limited , 1960; (3) New Brunswick Dept. of Natural Resources, 1975; (4) Eastern Gypsum Ltd., 1987

Appendix B (continued)

Drill Hole #	Overburden (meters)	Sampled interval (length in meters)	% gypsum	% anhydrite	Remarks
Roachville # 21[3]	18.2	-	-	-	Bedrock not intersected
87-1[4]	16.5	16.5-17.5 (2.0)	49.07	-	
		22.0-23.0 (1.0)	57.96	-	
		23.0-24.0 (1.0)	92.94	-	
		24.0-25.0 (1.0)	94.62	-	
		25.0-26.0 (1.0)	92.20	-	
		26.0-27.0 (1.0)	94.39	-	
		27.0-30.5 (3.5)	-	-	Gypsum with interbedded with limestone…. selenite (5mm) pseudomorphs (Whaley 1997)
87-2	8.2	8.2-30.5 (22.3)	-	-	Anhydrite….slightly gypsified 8.2-12 (Whaley 1997)
87-3	16.8	16.8-18.3 (1.5)	92.33	-	
		18.3-19.3 (1.0)	92.19	-	
		19.3-20.3 (1.0)	47.68	-	
		20.3 –30.5 (10.2)	-	-	Anhydrite
87-4	18.9	18.9-19.9 (1.0)	89.98	-	
		19.9-20.9 (1.0)	93.17	-	
		20.9-21.9 (1.0)	96.65	-	
		21.9-26.0 (4.1)	-	-	Gypsum….."ghost" anhydrite (Whaley 1997)
		26.0-30.5	-	-	Anhydrite
87-5	24.4	-	-	-	Bedrock not intersected

(1). Barrett Company Limited, 1956; (2). Gypsum Lime and Alabastine Limited 1960; (3) New Brunswick Dept. of Natural Resources, 1975; (4) Eastern Gypsum Ltd., 1987

Appendix B (continued)

Drill Hole #	Overburden (meters)	Sampled interval (length in meters)	% gypsum	% anhydrite	Remarks
60-2	6.1	6.1-6.7 (0.6)	**84.0**	13.6	Core recovery, 60 % in gypsum section
		6.7-7.2 (0.45)	**83.2**	5.0	
		7.9-10.4 (2.4)	**89.9**	5.8	
		10.4-11.9 (1.5)	**81.4**	14.5	
		11.9-14.0 (3.1)	37.2	**58.1**	
		14.0-18.3 (4.3)	9.7	**86.2**	
		18.3-46.3 (28.0)	-	-	Massive anhydrite
60-3	7.3	7.3-8.2 (0.9)	10.7	**86.6**	Good core recovery
		8.2-8.7 (0.5)	2.6	**95.4**	
		8.7-10.7 (2.0)	2.6	**95.6**	
		10.7-20.7 (10.0)	-	-	Massive anhydrite
60-4	5.2	5.2-5.5 (0.3)	12.5	**83.0**	Good core recovery
		5.5-6.1 (0.6)	7.5	**88.8**	
		6.1-9.1 (3.0)	4.6	**91.5**	
		9.1-13.1 (4.0)	-	-	Massive anhydrite
60-5	6.7(?)	6.0-9.1(3.1)	4.5	**86.3**	From 3.3-6.7 cavity reported
		9.1-14.3 (5.2)	-	-	Massive anhydrite

(1). Barrett Company Limited, 1956; (2). Gypsum Lime and Alabastine Limited , 1960; (3) New Brunswick Dept. of Natural Resources, 1975; (4) Eastern Gypsum Ltd., 1987

Appendix C. Summary of drilling (Dept. of Transportation, 2001) and chemical analysis for gypsum / anhydrite core samples intersected in the Roachville, Kennebecasis River 7.0 and Kennebecasis River Bridge 6.5 area, near the Town of Sussex, south-central New Brunswick (see D.O.T. 2001 on Figure 1and inset "Kennebecasis River 7.0", " Kennebecasis River Bridge 6.5 " and "Roachville" for location on Map Plate 2001-4, Appendix E). *Note: description and preliminary analysis by Dept. of Natural Resources and Energy (see Appendix D).*

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval in m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
Kennebecasis River 7.0							
BH-1	15.69	15.69 - **18.94**	1-1-7 (17.15-17.22)	0.06	13.94	66.91	Anhydritic gypsum breccia.
BH-1A	28.10	28.10 - **30.18**		-	-	-	Red mud / clay breccia
BH-1B	17.98	17.98 - **21.28**	1B-1-7 (18.64 -18.70)	0.06	15.85	76.08	Bedded gypsum (30°)
BH-2	16.38	16.38 - **25.83**	2-1-7 (16.84 - 6.90)	0.06	13.23	63.50	Interbedded white to dark grey anhydritic gypsum and gypsum, bedded (40°), with scattered selenite crystals.
			2-2-7 (24.2 - 24.31)	0.04	15.16	72.77	
BH-2A	14.73	14.73 - **16.98**	2A-1-7 (16.38 – 16.45)	0.09	12.91	61.97	White to grey anhydritic gypsum, bedded (50°)
			2A-2-7 (17.21 – 17.29)	0.03	15.82	75.93	White, massive gypsum

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
BH-2B	19.12	19.12 – **22.50**	2B-1-7 (19.65 – 19.70)	0.09	13.05	62.64	Anhydritic gypsum breccia with red silty matrix (clasts of gypsum and anhydrite)
		22.50 – **24.72**	2B-2-7 (23.63 – 23.72)	0.05	12.83	61.58	White, bedded (60°) anhydritic gypsum
BH-3	17.40	17.40 – **20.80**	3-1-7 (17.77 – 18.84)	0.10	15.46	74.19	White, massive gypsum
		20.80 – **21.51**	3-2-7 (21.11 – 21.51)	0.05	16.45	78.96	Gypsum, bedded (30°)
BH-3A	16.80	16.80 – 21.36	3A-1-7 (20.05 – 20.21)	0.09	12.95	62.16	White anhydritic gypsum
			3A-2 -7 (21.01 – 21.21)	0.04	15.98	76.70	
		21.36 – **26.02**	3A-3 -7 (23.58 – 23.72)	0.05	1.32	6.33	Medium to dark grey anhydrite with thin veins of selenite and minor danburite (?)
			3A-4 -7 (24.50 – 24.63)	0.02	0.93	4.46	
BH-3B	18.37	18.37- **21.64**	3B-1-7 (19.37 – 19.50)	0.06	12.57	60.34	White, bedded (40°) anhydritic gypsum and gypsiferous anhydrite

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval in m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
BH-4A	21.99	21.99 - **25.34**	-	-	-	-	Light grey anhydrite, bedded (50^o)
BH-4B	22.45	22.45 - **26.08**	-	-	-	-	Light grey anhydrite, bedded (30^o), minor danburite
BH-5	18.48	18.48 - 20.70	5-1-7 (19.52 – 20.52)	0.07	14.88	71.42	Gypsum breccia with small clasts of grey and red, calcareous, fine-grained sandstone
		20.70 - **21.52**	-	-	-	-	Light grey anhydrite
BH-5A	19.73	19.73 -**22.86**	5A-1-7 (20.53 – 20.60)	0.06	12.83	61.58	White, bedded anhydritic gypsum (30^o)
			5A-2-7 (21.31 – 21.36)	0.03	15.26	73.25	White gypsum
BH-5B	22.43	22.43 - **22.97**	5B-1-7 (22.43 – 22.93)	0.05	14.90	71.52	White gypsum
		22.97 - **26.13**	5B-2-7 (23.54 – 24.63)	0.04	17.36	83.33	
BH-6	23.36	23-36 - **23.60**	-	-	-	-	Light grey to dark grey anhydrite and gypsiferous anhydrite
		23.60 - **33.63**	6-1-7 (32.11 – 32.17)	0.06	1.40	6.72	

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval in m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
BH-6A (con't)	22.86	22.86 - **26.25**	-	-	-	-	Light grey to dark grey anhydrite. Bedding 40° to horizontal
Kennebecasis River Bridge 6.5							
BH-1	20.06	20.06 - **27.73**	-	-	-	-	Red brown, medium-grained sandstone with calcareous nodules
BH-1R	18.06	18.06 - **23.77**	-	-	-	-	Red mudstone breccia
		23.77 - **27.43**	-		-	-	Red brown, fine- to coarse-grained sandstone with small calcareous clasts
BH-1L	27.58	27.58 - **30.63**	-	-	-	-	Red brown, fine- to medium-grained sandstone with calcareous nodules
BH-2	23.16	23.16 - **28.65**					Red brown, fine- to coarse-grained sandstone with minor conglomerate
BH-2R	23.16	**23.16** +	-	-	-	-	Red-grey conglomerate with minor fine- to coarse-grained sandstone with calcareous nodules

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval in m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
BH-2L	23.01	23.01 - **29.01**	-	-	-	-	Red grey conglomerate with minor fine- to coarse-grained sandstone
BH-3	22.98	22.98 - **29.08**	-	-	-	-	Red grey conglomerate with minor medium - to coarse-grained sandstone
BH-3R	22.96	22.96 - 26.54	-	-	-	-	Red grey conglomerate
		26.54 - **26.94**	-	-	-	-	Red brown mudstone
BH-3L	23.16	23.16 - **27.43**	-	-	-	-	Red grey conglomerate with minor medium-grained sandstone
BH-4	25.90	25.90 - **28.95**	-	-	-	-	Medium grey, laminated limestone
BH-4L	25.90	25.90 - **29.41**					Medium grey, laminated limestone, bedding 40°
BH-4R	25.95	25.95 - **27.97**	-	-	-	-	Medium grey, laminated limestone, bedding 30°
BH-5	22.81	22.81- **27.43**	-	-	-	-	Red brown, medium-grained sandstone with limey nodules; bedding 40° to horizontal
BH-5R	22.70	22.70 - **25.75**	-	-	-	-	Red brown to red grey, fine- to medium- to coarse-grained sandstone with minor conglomerate
BH-5L	24.38	24.38 - **27.43**	-	-	-	-	Red brown, medium-grained sandstone with limey nodules

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval in m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
BH-6	22.90	22.90 - **27.12**	-	-	-	-	Red brown, fine- to medium-grained sandstone with limey nodules and minor conglomerate
BH-6R	21.41	21.41 - **26.82**	-	-	-	-	Red brown, medium-grained sandstone with limey nodules
BH-6L	23.16	23.16 - **29.26**	-	-	-	-	Red brown, fine- to medium-grained sandstone with limey nodules and minor conglomerate
BH-7	23.01	23.01 - **27.43**	-	-	-	-	Red brown medium-grained sandstone with minor conglomerate
BH-7R	23.01	23.01 - **26.06**	-	-	-	-	Red brown to red grey medium-grained sandstone and conglomerate
BH-7L	23.16	23.16 - **27.73**	-	-	-	-	Red brown to red grey conglomerate
BH-8	25.90	25.90 - **28.95**	-	-	-	-	Red grey conglomerate
BH-8R	24.81	24.81 - **29.08**	-	-	-	-	Red grey conglomerate
BH-8L	25.60	25.60 - **28.65**	-	-	-	-	Red grey conglomerate
Roachville							
BH- 1A	28.10	28.10 - 30.18	-	-	-	-	Red mud / clay breccia

Drill Hole #	Overburden (m)	Interval (m) **TD**	Sample # (interval in m)	% H_2O (free)	% H_2O (combined)	% Gypsum	Description
BH-1A (con't)		30.18 - 32.80	R-1A-1 (30.92 - 31.00)	0.10	14.04	67.42	White anhydritic gypsum breccia
		32.80 - **40.30**	-	-	-	-	Laminated red mud
BH-2	**36.27**	-	-	-	-	-	No bedrock
BH-3A	29.04	29.04 - **35.30**	R-3A-1 (31.62 - 31.70)	0.08	14.43	68.70	Light grey anhydritic gypsum breccia
			R-3A-2 (4.70 - 34.80)	0.08	13.25	64.03	
BH-4A	**33.80**	-	-	-	-	-	No bedrock

Appendix D. Chemical analysis for selected gypsum / anhydrite core samples intersected by New Brunswick Dept. of Transportation drilling (2001) in the Kennebecasis River 7.0 area, near the Town of Sussex, south-central New Brunswick (see inset "Kennebecasis River 7.0" for location on Map Plate 2001-4, Appendix E). *Note: analysis by Activation Laboratories Ltd. compared to preliminary analysis by Dept. of Natural Resources and Energy (see Appendix C).*

Drill Hole #	Sample #	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O + K_2O	SO_4	LOI	% H_2O (free)	% H_2O (combined)	% Gypsum (calculated)
BH-2	2-1-7	0.52	0.16	0.03	<0.001	0.02	32.31	<0.03	53.9	21.11	0.61	15.5	74.4
BH-5	5-1-7	0.36	0.09	0.02	<0.001	0.04	31.75	<0.02	51.4	21.14	0.83	15.5	74.4
BH-5B	5B-1-7	0.09	0.03	0.01	0.0002	0.06	32.00	<0.03	49.6	20.95	0.71	15.6	74.88

Appendix E. Guide to preliminary qualitative testing of gypsum samples.

Deposits of pure gypsum and anhydrite are usually easily distinguished from one another based on contrasting hardness, with gypsum being a much softer mineral. Despite this rather definitive characteristic, situations arise where incomplete hydration of anhydrite to gypsum will result in a co-mixture of the two minerals making the distinction somewhat less decisive.

Pure gypsum contains 20.9% combined water (H_2O), 46.6 % sulfur trioxide (SO_3) and 32.5% lime (CaO) in its mineral structure. The American Society for Testing Materials Designation C-22-50, has established 70% $CaSO_4 \cdot 2H_2O$ as a minimum purity standard for a substance to be referred to as *gypsum* (Havard 1960). Calcium sulphate with a combined water content of greater than 14.5% would therefore be called *gypsum* while combined water values <14.5 % and < 7.9 % might be referred to as *anhydritic gypsum* or *gypsiferous anhydrite,* respectively.

Although the following simple test procedure can be used to assist in the broad characterization of calcium sulphate samples (*i.e.* anhydrite → gypsiferous anhydrite → anhydritic gypsum → gypsum) proper qualitative tests (*i.e.* free H_2O, combined H_2O, SiO_2 and insoluble material, Fe_2O_3 and Al_2O_3, CaO, CO_2, MgO, SO_3 and NaCl) conducted in a qualified laboratory are required to establish the suitability of gypsum for specific end uses.

Water loss method for preliminary determination of gypsum.

1. *A crushed rock sample is crushed so that 100% passes a standard 2.5 mesh Tyler Sieve. A 50 to 100 gram sample is split and weighed to the nearest 1/100th of a gram.*

2. *The sample is spread out as a thin layer in a suitable vessel, placed in an oven and heated at 50-55 °C. After two hours sample is cooled and weighed again. The loss in weight is recorded as the free water content and reported as a percent of the sample weight as received.*

3. *The sample is reduced to pass a standard #60 (250 micron) Tyler Sieve.*

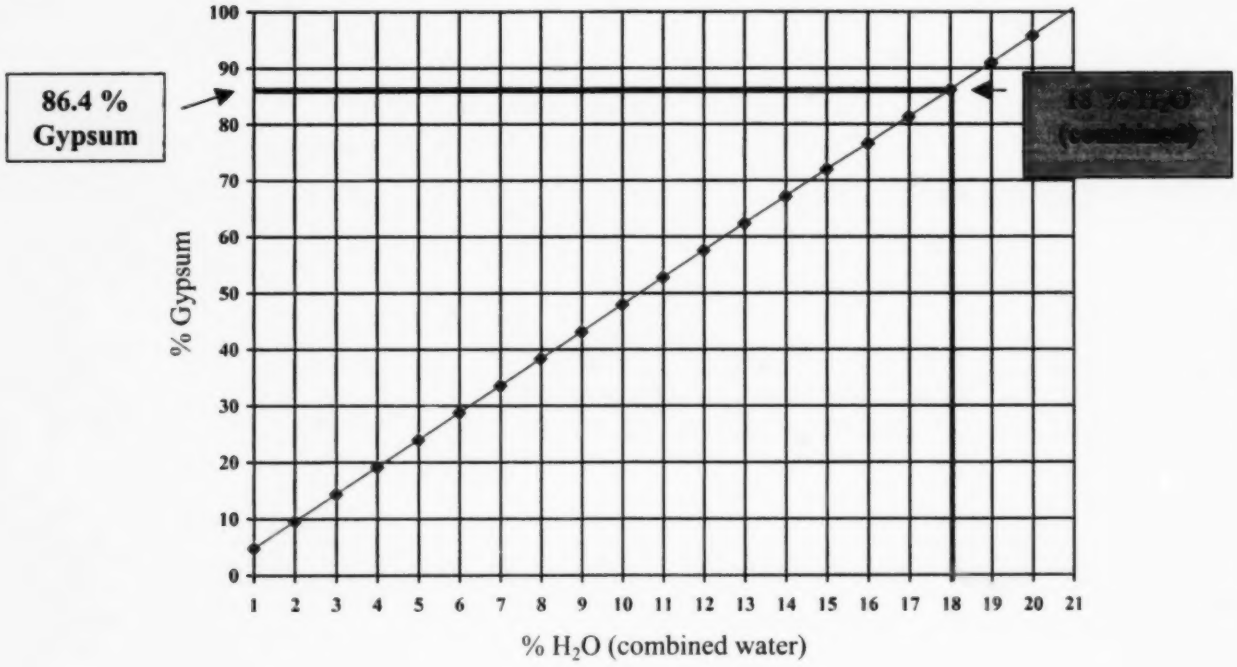
4. *A 5-10 gram portion of the reduced sample is placed in a suitable container and dried at 215-230 °C to a constant weight. The loss of weight is recorded and reported as a percentage of combined water in the sample. Since pure gypsum maintains a maximum of 20.9% combined water it is possible to establish a linear relationship between the % water loss and the % gypsum content:*

$$\frac{100\ \%\ gypsum}{1\%\ gypsum} = \frac{20.9\%\ H_2O}{x\ \%\ H_2O} \qquad \frac{100x}{20.9} = 4.8$$

Therefore for each % of water loss is equivalent to 4.8 % gypsum

Appendix E (continued)

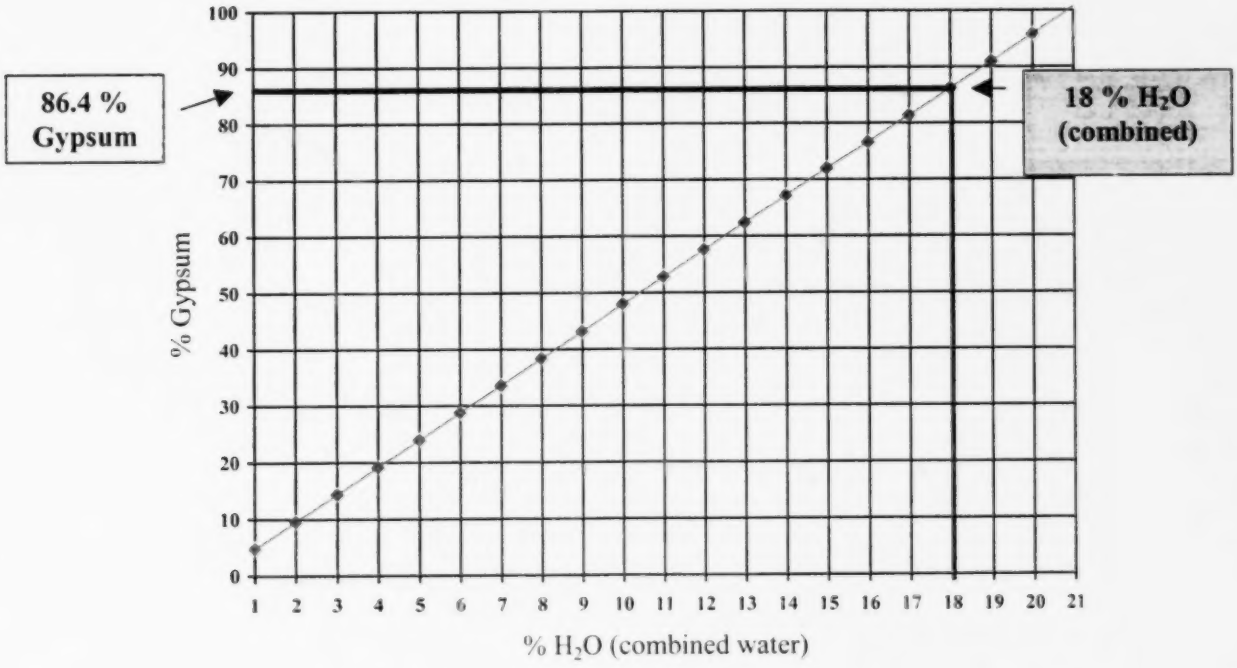
5. *The % of gypsum in each sample can then be calculated by multiplying the results of step 4 by 4.8 or by comparing the % combined water loss to the corresponding % gypsum on the graphical representation below:*



Example: 18 % combined H_2O (x 4.8) = 86.4 % gypsum

Appendix E (continued)

5. *The % of gypsum in each sample can then be calculated by multiplying the results of step 4 by 4.8 or by comparing the % combined water loss to the corresponding % gypsum on the graphical representation below:*



Example: 18 % combined H_2O (x 4.8) = 86.4 % gypsum

Appendix F

Map Plate 2001-4. Carboniferous geology and gypsum / anhydrite resources of the Sussex area, (parts of NTS 21 H/12 and 21 H/13), Kings County, south-central New Brunswick

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